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MATERIALS PROCESSING

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EFFECT OF THE ACTIVE COMPONENTS OF POLISHING COMPOSITIONS ON THE DISPERSION OF THE SURFACE LAYER OF RUBY DURING FINE ABRASIVE MACHINING

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An investigation of the products of wear (sludge) formed during fine diamond-abrasive polishing of ruby showed that the sizes of the particles split off the worked surface depend strongly on the properties of the surface-active components of the polishing composition. The results obtained must be taken into account in the development of polishing compositions making it possible to increase the productivity of fine abrasive machining and improve the surface quality of articles.

Key words: Rebinder effect, dispersion, polishing.

Many forms of abrasive machining, including fine finishing and polishing, comprise a combination of plastic deformation and very fine dispersion of the surface layer of the machined material.

Surface-active substances have a large effect on the formation of the crystalline structure and micro-relief of the surface of a material being machined. The basis of this phenomenon is the Rebinder effect [1].

The roughness of a surface can be reduced to a minimum either by smoothing the surface or by separating very small particles (nanoparticles) from it.

In the first case (smoothing of the surface by means of plastic deformation) the surface layer must be plasticized [2, 3].

In the second case (dispersing the surface) it is necessary to use a surface-active medium, which gives the maximum reduction of the strength of the surface layer of the material, decreasing the work of dispersion right up to embrittlement.

In a previous work we showed the selective action of surfactants on the weakening of interatomic bonds in the crystal lattice of ruby in definite crystallographic planes [4].

The objective of the present work was to investigate the effect of different surface-active media on the dispersity of the particles of sludge (wear particles) as well as on the formation of the crystallographic structure of these particles. We also investigated the crystalline structure of a ruby surface from which the particles of sludge separated.

The ruby samples with a perfect single-crystalline structure were polished with a suspension of diamond powder with dispersity 28 μm in the (111) plane. Ethylene glycol, diethylene glycol and oleic acid were used as the surface-active dispersion media. The abrasive machining of the samples was performed on a surface grinder.

The ruby wear particles (sludge) formed during polishing were carefully washed to remove the dispersion medium using the appropriate solvents and dried. Next, a suspension of ruby particles in ethyl alcohol was deposited on a thin (100 Å) graphite film. The objects prepared in this manner were investigated by means of electron microscopy and electron diffraction in transmission. The method of precision electron diffraction made it possible to obtain a diffraction pattern from individual particles of sludge.

The electron-microscopic studies showed that the dispersity of the ruby particles formed in the process of fine abrasive machining largely depends on the physical-chemical properties of the surface-active components of the polishing medium. The largest particles (1 μm) split off a ruby surface in diethylene glycol. The average size of the particles formed during the machining of ruby in ethylene glycol and oleic acid were found to be 10 times smaller (0.1 μm).

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These results show indirectly a significant reduction of the ruby layer under the influence of the specially selected surface-active medium.

An investigation of the crystalline structure of individual sludge particles by means of electron micro-diffraction in transmission showed that these particles have a perfect single-crystalline structure.

Together with electron diffraction, the method of powder x-ray diffraction was used, making it possible not only to perform a phase analysis but also to determine the stress in the particles. Copper radiation was used for the x-ray photography.

The x-ray diffraction analysis showed that the phase composition of all three wear products, obtained in ethylene glycol, diethylene glycol and oleic acid, is that same and corresponds to Al_2O_3. The values of the interplanar distances on the powder patterns obtained correspond to the structure of single-crystalline corundum, which attests to the absence of stress in the sludge particles.

It can be concluded on the basis of the electron and x-ray diffraction studies that in these cases the sludge particles formed as a result of polishing a ruby single crystal possess an undistorted single-crystal structure.

A different picture was observed in an electron-diffraction study of the parent surfaces of ruby samples, the abrasive machining of which led to the formation of the sludge.

The studies performed on an electron diffractometer equipped with a gun for removing electric charge from the surface of the samples showed that as a result of abrasive machining in all three dispersion-lubricating media the very thin (100 Å) surface layer of the ruby samples possessed a strongly distorted, nearly amorphous, crystalline structure.

The apparent paradox — the strongly distorted amorphous surface of a monolithic sample on the one hand and undistorted single-crystalline wear particles (sludge) on the other hand — can be explained by the elastic restoration of the shape of the particles split off and the relaxation of the stresses in them.

The relaxation processes occurring in a strongly distorted polycrystalline surface layer of a monolithic sample are impeded by a scale factor, because the elastic deformation of each individual crystallite is fixed by neighboring crystallites.

CONCLUSIONS

It was shown that surface-active substances present in polishing compositions have a large effect on the dispersal of the surface layer of ruby during diamond abrasive polishing.

The sizes of the sludge particles formed during diamond abrasive polishing of ruby depend strongly on the properties of the surface-active components of the polishing composition.

The largest particles (1 μm) split off the ruby surface during polishing in a diethylene glycol medium. The average size of the particles formed in ethylene glycol and oleic acid was found to be 10 times smaller (0.1 μm).

These results show that as a result of the Rebinder effect a specially chosen surface-active medium can reduce significantly the work of dispersion of the surface layer of a solid.

The results obtained must be taken into account when formulating polishing compositions that the productivity of fine abrasive machining and improve the surface quality of articles.

REFERENCES

1. P. A. Rebinder, *Report at the 6th Conference of Russian Physicists* [in Russian], OGIZ, Moscow (1928).
2. A. A. Kanaev, V. N. L'vov, S. Ya. Veiler, and P. A. Rebinder, "Observation of adsorption plasticization of the surface layer of a metal under the influence of active lubrication in the presence of surface friction," *Dokl. Akad. Nauk SSSR*, **187**(2), 314 – 317 (1969).
3. A. A. Kanaev, V. N. L'vov, V. S. Luk'yanov, et al., "Effect of the boundary conditions on the deformation of a very thin surface layer of solids," *Dokl. Akad. Nauk SSSR*, **206**(3), 586 – 589 (1972).
4. A. A. Kanaev and A. E. Gorodetskii, "Formation of the crystal structure of a ruby surface under the influence of surface-active media in the process of diamond polishing," *Steklo Keram*., No. 2, 31 – 32 (2007); A. A. Kanaev and A. E. Gorodetskii, "Formation of the crystal structure of the surface of ruby under the effect of surface-active media in diamond polishing," *Glass Ceram*., **64**(1 – 2), 66 – 67 (2007).